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The Potential of Local Plants as Bioindicators of Air Ambient Quality

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ABSTRACT

Air pollution can cause damage to human health, be it acute or chronic, that is why it is important that ambient air quality be determined which does not prove to be easy for common people. This study investigated the potential of three plant species, *Dracaena surculosa* (Fortune Plant), *Cocos nucifera* (Coconut), and *Musa paradisiaca* (Banana) as bioindicators of ambient air quality. Sampling was done in three different locations in Zamboanga City namely Zamboanga City Medical Center in Sta. Catalina, PHIDCO in Baliwasan, and Environmental Management Bureau in Pasonanca. Picture of each leaf sample was taken and subjected to Image J program to get the DCA of each leaf. One-way Analysis of Variance was used to test the significant differences in the mean DCA of each group of leaves in the three research locale and in the mean DCA of each leaf species in the three research locales while pairwise comparison was done using Tukey Post-hoc test among groups of leaves in each locale and by leaf species. This study revealed that among the three sampling stations Zamboanga City Medical Center in Sta. Catalina has the least DCA of leaves which means that these is the most polluted among three which may be contributed to pollution in the area caused by too much traffic. It was also found out that among the three plant species tested, *Cocos nucifera* ha the least mean DCA which means that it has the highest potential as bioindicator of ambient air quality. More studies may be conducted to validate the results of this study and to find more bioindicators of air quality.

Keywords : wettability, hydrophilic, hydrophobic, Drop Contact Angle, Zamboanga City.

INTRODUCTION

THE release of chemical pollutants to air is damaging to people and the planet as a whole or air pollution is one of the world's major problems today. Globally, more than 2 million people die every year from air pollution is reported by the World Health Organization (WHO). Among all the air pollutants, fine particulate matter (PM) is one of the hazardous pollutions to health. It causes about 9% of lung cancer, 5% of cardiopulmonary deaths and about 1% of respiratory infection deaths. The World Health Organization revealed that there is mounting evidence that the concentration of particulate matter is increasing in Asia. Dust from grassland fires, dust storms, burning of fossil fuels in vehicles are some sources of particulate matter, industrial plants give out significant amounts of particulates as well.

The Philippines is one of the countries that carry a voluminous amount of air pollution. The country experienced worsening air pollution in recent years and presents a threat to human life. On the previous years, the World Health Organizationreported that the Philippines ranked third in mortality rate caused by air pollution (recap.asia, 2017). And the main reason why the Philippines ranked high in the recent Air Quality Report is an insufficient air monitoring system.

Due to an inadequate air monitoring system, the Environmental Management Bureau implemented the R.A 8749, also known as the "Philippine's Clean Air Act". Its primary goal is to come out with a comprehensive national program to achieve and maintain Air Quality that meets the National Air Quality Guidelines for Criteria Pollutants and their Emissions Standards. Its implementing rules and regulation contain a specific requirement that prohibits the vehicular and industrial sources from emitting pollutants in amounts that cause significant deterioration of air quality, dust from construction work, car emissions and traffic congestions are the main reasons of air pollution (Catalina Ricci S. Madarang, 2019).

Various types of activity, including agriculture, industry, and transportation, produce a large number of wastes and new types of

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pollutants in air (Setyorini et al., 2002).

Pollutants are the substances that contaminate air, water and or soil. Nitrogen dioxide (NO2), Carbon Monoxide (CO), and Hydrocarbons (HC) are considered the main emissions, and higher levels can often be the result of increased airport vehicular traffic (Yang and Liu, 2011) Pollutants are not necessarily born as pollutants. Incorrect uses, accidental releases and/or technical limits make them harmful to our environment (Zhai, 2011).

Most of the sources of air pollution are related to human activities as a result of the modern lifestyle. The main pollution sources include chemicals, industries, automobiles, coal-fired power plants, nuclear waste disposal activity, plastic factories, etc. Agriculture air pollution comes from spraying of pesticides and herbicides. Harmful effects of pollution have both acute and chronic effects on human health. Health effects range anywhere from minor irritation of eyes and upper respiratory systems, heart disease, lung cancer, and death. Ozone depletion is the result of air pollution. The air pollution control is the process of reducing the release of pollutants from industries, wastes of chimneys, fossil-fuel (coal), thermal power plants, etc. It is regulated by various environmental agencies that establish limits for the discharge of pollutants into air (Singh, 2013). The control of emissions can be realized in the number of ways such as collection of pollutants, cooling, emission control in automobile engines (Sharma, 2014). The planting of ornamental plants for the control of pollution and improvement of environment is an effective way. The proper planning and planting scheme depends upon the type of pollution. Tolerants and dust absorbing trees and shrubs should be planted for bioremediation of environment.

Through these causes, some areas, both national and local, are being completely blanketed by polluted air and causes the leaves near polluted areas being coated with particle pollutants which may cause occlusion leading to reduced photosynthesis thus, the coating also changes the micromorphology, chemical, and composition and the amount of wax on the surface of the leaves.

Wettability in leaves is a phenomenon that is happing to plants and its relationship to water absorption. The angle measurement of water contact to leaves is a measurement of an index of leaf's surface wettability. Internal and external factors can influence the leaf's wettability. According to Wang, et.al. (2015), there are signs and fragments of leaves wettability influenced by different factors, internal causes in the leaf surfaces like chemical composition and leaf structure; and external causes like surface wax, trichrome, stomatal density, the shape of cells and status of water on a leaf.

Changes in structures, composition and other leaves' conditions are the effect of pollutants can be inferred from changes in the measures of contact angles of water in the leaf surface. Thus, leaf wettability can be a good indicator, complementary to other bio-indicators as e.g., anatomical and physiological leaf characteristics, to estimate differences in urban habitat quality. Most of the previous researches evaluated leaf wettability as an indicator for simulated acid rain, sole pollutant or at most a combination of some pollutants. There was relatively less investigation on the effect of ambient air pollution in the country or even abroad, that is, the effect of leaves when exposed to gaseous pollutants in outdoor conditions.

Richard Jagels (1994) conducted a similar study which showed leaf wettability as an indicator of the level of pollution in the air through the method of droplet contact angle or DCA. In DCA technique, air pollution can be detected through the changes and leaf condition; it was also found that in a place where the level of pollution is high, the DCA level of measurement is reduced.

The important criteria for the ornamental plants to be phytoremetioter for air pollution are plants should be evergreen, large-leaved, rough bark, indigenous, ecologically compatible, low water requirement, minimum care, high absorption of pollutants, resistant pollutants, agro-climatic suitability, height, and spread,

The amount of air-borne pollutants removed increases with leaf surface area. Therefore, trees tend to be better filters than shrubs and grasses. Due to their large surface area and year-round coverage, conifers (evergreens) are very good pollution filters. However, conifers tend to be sensitive to phytotoxic air pollutants and deciduous trees are more efficient at absorbing gaseous pollutants. It is, therefore, beneficial to have a mixture of species in order to have the greatest effect in reducing air pollution (Bolund and Hunhammar 1999).

So, in this study, the researcher will investigate the wettability of the common plant species in the areas in Zamboanga City Medical Center, Philippine International Development Incorporated or PHIDCO-Baliwasan, and Environmental Management Bureau-Pasonanca of Zamboanga City that this study will recommend an alternative way of measuring air quality through leaves.

METHODOLOGY

This study was conducted in three (3) different areas/sites Zamboanga City: Zamboanga City Medical Center Sta. Catalina, Philippine International Development Incorporated, Baliwasan, and Environmental Management Bureau, Pasonanca, since these areas are in city but different location with different volume of traffic, different number of households, and different in terms of industries present in the area, terrain and slope.

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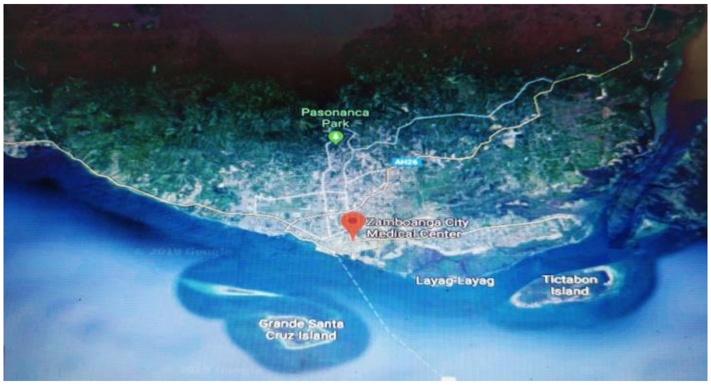

Fig. 1. Location of Zamboanga Medical Center, PHIDCO and Environmental Management Bureau

This study used the descriptive-comparative research design. Descriptive research is used to gather information about the present and existing conditions. This research expresses the present condition of the situation. It involves the gathering, analyzing, and tabulating the collated data to see relationships between variables (Aguinaldo, 2002). This method considers variables and establishes a formal procedure to compare the variables understudy and conclude that one variable is better than the other. (Calmorin, 2016). In this study the researcher investigated the wettability properties (dependent variable) of the leaves of the three plants used in the three research locales using the DCA test to determine their potentials as air quality indicator.

In chosen locale of the study – industrial or urban and semi-natural or rural areas, three (3) plants were selected as research specimens, namely *Dracaena surculosa* (Fortune plant), *Cocosnucifera* (Coconut), and *Musa paradisiaca* (Banana). Ten (10) healthy leaves were taken as samples for each kind of plant for ten (10) series of tests. This was done on the day that no rain occurred within five days before the sampling will be. After cutting, the leaf samples were transported immediately through a box to the laboratory for leaf analysis. During the test, only the adaxial (front) side of the leaves were measured using Drop Contact Angle of DCA.

In the preparation of the leaf samples, each leaf was handled and cut thoroughly into a rectangular shape, excluding the major veins to provide a flat surface in order not to affect the water droplets and surface interaction. The cut-out leaf samples were then mounted on a glass slide using double-sided tape. The samples were placed on the top black cloth for viewing clarity along with a ruler for scaling purpose (Salazar, Jefferson, 2014).

Using a syringe, distilled water drops were placed on the topside of the leaf surface with a distance of about half a droplet apart to ensure the thorough separation 0f droplets. Using the DSLR camera, an up close photo of the droplets was taken. The same process was being performed in the other leaf samples. The picture taken were processed with the used of ImageJ to determine the contact angle. Evey drop was cropped from the actual picture and converted into 8-bit image. The DropSnake Plugin of ImageJ estimated the contact angle by tracing points of the nearly spherical drop. (Salazar, Jefferson, 2014).

The following statistical tools that were utilized to compute and analyze the data to be collected are the percentage, frequency distribution, Pearson Correlation, and Analysis of Variance. Percentage is used to get the central tendency of data, and this iused to determine the percentages of the whole data observed. (Calmorin, 2009). To summarize the responses made by the respondents during the conduct of the study, frequency distribution will be used (Adanza, 2009). An Independent T-test will be used to make an inference by determining whether there is statistical significant difference between the means of three leaves in terms of drop contact angles (Calmorin, 2016). Lastly, Analysis of Variance (ANOVA) is used to learn if there is a significant differencebetween the values of mean DCA of leaf groups gathered from different areas (Calmorin, 2010).

RESULTS AND DISCUSSION

The following tables present the analysis and interpretation of data on the wettability of the common plant species in the areas in Zamboanga City Medical Center, Philippine International Development Incorporated or PHIDCO-Baliwasan, and Environmental Management Bureau-Pasonanca of Zamboanga City.

Table 1. Mean DCA of the leaves of each specie in groups by area.

Location	Species	Left	Right	Overall Mean	Interpretation
Location 1 (ZCMC)	Coconut	57.18	54.31		
	Banana	78.88	76.17	60.28	Wettable
	Fortune Plant	46.67	48.46		
Location 2 (PHIDCO)	Coconut	60.83	63.41		
	Banana	60.03	63.60	62.14	Wettable
	Fortune Plant	61.93	63.02		
Location 3 (EMB)	Coconut	72.63	74.22		
	Banana	68.73	69.66	74.82	Wettable
	Fortune Plant	80.57	83.10		

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	68.97	Wettable

The mean Drop Contact Angle (DCA) of the leaves in three different research locales. In the first location (ZCMC) it has an average mean DCA of 60.28, for location 2 (PHIDCO) it has an average mean DCA of 62.14, and in location 3 (EMB) it has an average mean DCA of 74.82. The lowest means of DCA for leaf surface were observed in area of PHIDCO-Baliwasan and followed by ZCMC. The highest DCA of leaf was found in the area of EMB – Pasonanca. It was indicated in the table that in all three (3) locations all mean DCA of leaves that were under observations were wettable since all average mean were within the range of 0 degree to 90 degrees which is wettable. This means that all leaves were hydrophilic, that water has the ability to maintain contact with in the solid surface of the leaves. For wettable or high-wettable leaf surfaces with low contact angles (< 90°), the much larger contact area may lead to much stronger force between particles and leaf surfaces. Accordingly, highly-wettable surfaces, which promote the accumulation and deposition of particles on leaf surfaces, make them appropriate species for air quality indicator (Yao, 2015).

Testing of the Hypothesis

The following hypotheses were tested for validity using 0.05 level of significance.

1. There is no significant difference in the mean averages in the DCA of leaf groups gathered in the three (3) research locales, Zamboanga City Medical Center, Philippine International Development Incorporated or PHIDCO-Baliwasan, and Environmental Management Bureau-Pasonanca of Zamboanga City,
   This hypothesis was tested using the One-Way Analysis of Variance (ANOVA) with results shown in Table 2.

Table 2. Testing of significant difference on the values of mean DCA of leaf groups by research locale using ANOVA.

Source of Variation	Sum of squares	Df	Mean Square	F	p-value	Interpretation
Between Groups	7944.973	2	3972.487	34.055	.000	With Significant Difference
Within Groups	20646.953	177	116.649			
Total	28591.926	179				

As revealed in the findings the F-value is 34.055 and p-value of 0.000 which is less than 0.05 level of significant. The data implied that there was a significant difference among the mean averages in the DCA of leaf groups gathered in the three (3) research locales; therefore, null hypothesis is rejected.

Table 3. Pairwise comparison of the mean DCA of leaf groups by research locale using Tukey post-hoc test.

Species Pairwise Comparison	Mean Difference	Std. Error	p-value	Interpretation
Location 1 (ZCMC)-Location 2 (PHIDCO)	-1.94948	1.97188	.585	No Significant Difference
Location 1 (ZCMC) - Location 3 (EMB)	-14.96667*	1.97188	.000	With Significant Difference
Location 2 (PHIDCO)-Location 3 (EMB)	-13.01718*	1.97188	.000	With Significant Difference

The table shows the Pairwise comparison of the mean DCA of leaf groups by research locale using Tukey post-hoc test. Results showed that between Locations 1 and 3 the p-value is .000 while in Locations 2 and 3 p-value is .000 which means that there is a significant difference in the mean DCA of leaf groups in the areas being compared. However, in Locations 1 and 2 p-value was .585 which means that there is no significant difference in their mean DCA value of the leaves in both sites.

A significant difference was revealed in the mean DCA values of each leaf groups in the three sampling sites (Table 2). However, pairwise comparison using Tukey post-hoc test showed that only in Locations 1(ZCMC-Sta. Catalina) and 3(EMB- Pasonanca) and Locations 2 (PHIDCO-Baliwasan) and 3(EMB-Pasonanca) showed significant differences in the mean DCA of the leaf groups while there is none between Locations 1 and 2. These differences may be attributed to geographic location, pollution it contributes and surrounding environment. Since the Zamboanga City Medical Center is located nearby the intersection area of all the vehicles going in and through the city proper or pueblo, the traffic density is higher during rush hours. Traffic jams, and thus the high production of combustion residues from engine vehicle. In the area of Pasonanca, it is located in hilly place and more trees can be found in this area and its surrounding barangays; and on the other hand, barangay Baliwasan is a highway passage through Ayala area where all types of vehicles can

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pass through this area. These findings are in consonance with the data gathered from the Department of Environment and Natural Resources- Environmental Management Bureau from year 2017 to June 2019 that ZCMC in Barangay Sta. Catalina is more densely covered with particulate matter as compared to PHIDCO in Baliwasan, and EMB in Pasonanca which is a protected area of Zamboanga City with the least particulate matter among the three sites.

Table 4. Mean DCA of the leaves by species in the three sampling sites

Species	Left	Right	Overall Mean	Interpretation
Coconut	63.55	63.98	63.76	Wettable
Banana	69.21	69.81	69.51	Wettable
Fortune Plant	63.05	64.86	63.96	Wettable

Based on the results, all species were wettable, with *(Musa Paradisiaca)* banana in the first rank with an overall mean of 69.51, followed by (*Dracaena surculosa)* fortune plant with overall mean of 63.96, and with a slight difference from the second species, (*Cocos-Nucifera)* coconut ranked third with an overall mean of 63.76. This means that coconut has higher wettability properties compared to other two species.

2. There is no significant difference on the mean DCA values of each leaf species in the three research locales

Table 5. Testing of significant difference on the values of mean DCA of leaf species in the three research locales using ANOVA.

Source of Variation	Sum of squares	Df	Mean Square	F	p-value	Interpretation
Between Groups	1233.712	2	616.856	3.991	.020	With Significant Difference
Within Groups	27358.215	177	154.566			
Total	28591.926	179				

The testing of hypothesis on the mean DCA values of each leaf species in the three research locales yielded a p-value of .020 which is less than 0.05 hence, the null hypothesis is rejected and established a significant difference among the three.

Table 6. Pairwise comparison of each leaf species in the three research locales using Tukey post-hoc test.

Species Pairwise Comparison	Mean Difference	Std. Error	p-value	Interpretation
Coconut-Banana	-5.83853*	2.26985	.029	With Significant Difference
Coconut-Fortune plant	-.62222	2.26985	.959	No Significant Difference
Banana – Fortune plant	5.21632	2.26985	.059	No Significant Difference

Results showed that the p-value for Coconut-Banana is 0.29 which means that there is a significant difference in their mean DCA values while p-values for Coconut-Fortune plant and Banana-Fortune plant are .959 and .059 respectively. This means that there is no significant difference in the mean DCA values of each pair of leaves.

All three species exhibit wettability of their leaves. Table 5 revealed that there is a significant difference in the mean DCA values of each leaf species in the three sampling sites. However, pairwise comparison using Tukey post-hoc test showed that significant difference is established only between Coconut and Banana while there is none between Coconut and Fortune plant and Banana and Fortune plant. These differences in the wettability of the leaves may be attributed to leaf's characteristics like wax and pollutants present on the leaf surface according to Wang (2015), leaf wettability influences pollutant deposition such as acid rain, ozone, and particulate matter, and in the interception of precipitation. In this case, coconut is wettable than other two species due to its lower contact angles in the leaf surface. In this study, drop contact angle varied between species, and leaf surface. According to Kardel et al. (2015), a species with wax, hydrophobic leaf surface, expressed by a large drop contact angle or small leaf wettability, is unable to accumulate many magnetic particles on its surface like species with a hydrophilic leaf surface (large leaf wettability).

According to the study conducted by Aryal (2010), leaves from tropical regions were non wettable, but for this research study species that were under study were all wettable proving that waxy cuticles increase the wettability or hydrophobicity and facilitate the removal of polluted particles from leaf surface.

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CONCLUSION

All three plant species used as research specimen proved to have a potential as bioindicators of ambient air quality. However, among the three plant species, coconut is the best bioindicator followed by fortune plant and subsequently, banana. Since coconut can withstand and accumulate higher concentration of pollutants owing to their large biomass and size.

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